

of at least 5 Hz. Use these recorded values to calculate cycle-validation statistics and total work.

(d) For constant-speed engines, operate the engine with the same production governor you used to map the engine in §1065.510 or simulate the in-use operation of a governor the same way you simulated it to map the engine in §1065.510. Command reference torque values sequentially to perform a duty cycle. Issue torque commands at a frequency of at least 5 Hz for transient cycles and at least 1 Hz for steady-state cycles (*i.e.*, discrete-mode, ramped-modal). Linearly interpolate between the 1 Hz reference values specified in the standard-setting part to determine more frequently issued reference torque values. During an emission test, record the feedback speeds and torques at a frequency of at least 5 Hz for transient cycles and at least 1 Hz for steady-state cycles. For transient cycles, you may record the feedback speeds and torques at lower frequencies (as low as 1 Hz) if you record the average value over the time interval between recorded values. Calculate the average values based on feedback values updated at a frequency of at least 5 Hz. Use these recorded values to calculate cycle-validation statistics and total work.

(e) You may perform practice duty cycles with the test engine to optimize operator demand and dynamometer controls to meet the cycle-validation criteria specified in §1065.514.

[73 FR 37317, June 30, 2008]

§ 1065.514 Cycle-validation criteria for operation over specified duty cycles.

Validate the execution of your duty cycle according to this section unless the standard-setting part specifies otherwise. This section describes how to determine if the engine's operation during the test adequately matched the reference duty cycle. This section applies only to speed, torque, and power from the engine's primary output shaft. Other work inputs and outputs are not subject to cycle-validation criteria. You must compare the original reference duty cycle points generated as described in §1065.512 to the corresponding feedback values recorded

during the test. You may compare reference duty cycle points recorded during the test to the corresponding feedback values recorded during the test as long as the recorded reference values match the original points generated in §1065.512. The number of points in the validation regression are based on the number of points in the original reference duty cycle generated in §1065.512. For example if the original cycle has 1199 reference points at 1 Hz, then the regression will have up to 1199 pairs of reference and feedback values at the corresponding moments in the test. The feedback speed and torque signals may be filtered—either in real-time while the test is run or afterward in the analysis program. Any filtering that is used on the feedback signals used for cycle validation must also be used for calculating work. Feedback signals for control loops may use different filtering.

(a) *Testing performed by EPA.* Our tests must meet the specifications of paragraph (f) of this section, unless we determine that failing to meet the specifications is related to engine performance rather than to shortcomings of the dynamometer or other laboratory equipment.

(b) *Testing performed by manufacturers.* Emission tests that meet the specifications of paragraph (f) of this section satisfy the standard-setting part's requirements for duty cycles. You may ask to use a dynamometer or other laboratory equipment that cannot meet those specifications. We will approve your request as long as using the alternate equipment does not adversely affect your ability to show compliance with the applicable emission standards.

(c) *Time-alignment.* Because time lag between feedback values and the reference values may bias cycle-validation results, you may advance or delay the entire sequence of feedback engine speed and torque pairs to synchronize them with the reference sequence. If you advance or delay feedback signals for cycle validation, you must make the same adjustment for calculating work. You may use linear interpolation between successive recorded feedback signals to time shift an amount that is a fraction of the recording period.

(d) *Omitting additional points.* Besides engine cranking, you may omit additional points from cycle-validation statistics as described in the following table:

TABLE 1 OF § 1065.514—PERMISSIBLE CRITERIA FOR OMITTING POINTS FROM DUTY-CYCLE REGRESSION STATISTICS

When operator demand is at its . . .	you may omit . . .	if . . .
For reference duty cycles that are specified in terms of speed and torque (f_{href} , T_{ref})		
minimum	power and torque	$T_{\text{ref}} < 0\%$ (motoring).
minimum	power and speed	$f_{\text{href}} = 0\%$ (idle speed) and $T_{\text{ref}} = 0\%$ (idle torque) and $T_{\text{ref}} - (2\% \cdot T_{\text{max mapped}}) < T < T_{\text{ref}} + (2\% \cdot T_{\text{max mapped}})$.
minimum	power and either torque or speed.	$f_n > f_{\text{href}}$ or $T > T_{\text{ref}}$ but not if $f_n > (f_{\text{href}} \cdot 102\%)$ and $T > T_{\text{ref}} \pm (2\% \cdot T_{\text{max mapped}})$.
maximum	power and either torque or speed.	$f_n < f_{\text{href}}$ or $T < T_{\text{ref}}$ but not if $f_n < (f_{\text{href}} \cdot 98\%)$ and $T < T_{\text{ref}} - (2\% \cdot T_{\text{max mapped}})$.
For reference duty cycles that are specified in terms of speed and power (f_{href} , P_{ref})		
minimum	power and torque	$P_{\text{ref}} < 0\%$ (motoring).
minimum	power and speed	$f_{\text{href}} = 0\%$ (idle speed) and $P_{\text{ref}} = 0\%$ (idle power) and $P_{\text{ref}} - (2\% \cdot P_{\text{max mapped}}) < P < P_{\text{ref}} + (2\% \cdot P_{\text{max mapped}})$.
minimum	power and either torque or speed.	$f_n > f_{\text{href}}$ or $P > P_{\text{ref}}$ but not if $f_n > (f_{\text{href}} \cdot 102\%)$ and $P > P_{\text{ref}} + (2\% \cdot P_{\text{max mapped}})$.
maximum	power and either torque or speed.	$f_n < f_{\text{href}}$ or $P < P_{\text{ref}}$ but not if $f_n < (f_{\text{href}} \cdot 98\%)$ and $P < P_{\text{ref}} - (2\% \cdot P_{\text{max mapped}})$.

(e) *Statistical parameters.* Use the remaining points to calculate regression statistics described in §1065.602. Round calculated regression statistics to the same number of significant digits as the criteria to which they are compared. Refer to Table 2 of §1065.514 for the default criteria and refer to the standard-setting part to determine if there are other criteria for your engine. Calculate the following regression statistics:

- (1) Slopes for feedback speed, a_{1f} , feedback torque, a_{1T} , and feedback power a_{1P} .
- (2) Intercepts for feedback speed, a_{0f} , feedback torque, a_{0T} , and feedback power a_{0P} .
- (3) Standard estimates of error for feedback speed, SEE_{f} , feedback torque, SEE_{T} , and feedback power SEE_{P} .
- (4) Coefficients of determination for feedback speed, r^2_{f} , feedback torque, r^2_{T} , and feedback power r^2_{P} .

(f) *Cycle-validation criteria.* Unless the standard-setting part specifies otherwise, use the following criteria to validate a duty cycle:

- (1) For variable-speed engines, apply all the statistical criteria in Table 2 of this section.
- (2) For constant-speed engines, apply only the statistical criteria for torque in Table 2 of this section.
- (3) For discrete-mode steady-state testing, apply cycle-validation criteria by treating the sampling periods from the series of test modes as a continuous sampling period, analogous to ramped-modal testing and apply statistical criteria as described in paragraph (f)(1) or (f)(2) of this section. Note that if the gaseous and particulate test intervals are different periods of time, separate validations are required for the gaseous and particulate test intervals. Table 2 follows:

TABLE 2 OF § 1065.514—DEFAULT STATISTICAL CRITERIA FOR VALIDATING DUTY CYCLES

Parameter	Speed	Torque	Power
Slope, a_1	$0.950 \leq a_1 \leq 1.030$	$0.830 \leq a_1 \leq 1.030$	$0.830 \leq a_1 \leq 1.030$.
Absolute value of intercept, $ a_0 $	$\leq 10\%$ of warm idle	$\leq 2\%$ of maximum mapped torque.	$\leq 2\%$ of maximum mapped power.
Standard error of estimate, SEE	$\leq 5\%$ of maximum test speed	$\leq 10\%$ of maximum mapped torque.	$\leq 10\%$ of maximum mapped power.
Coefficient of determination, r^2	≥ 0.970	≥ 0.850	≥ 0.910 .

[73 FR 37318, June 30, 2008, as amended at 73 FR 59330, Oct. 8, 2008; 75 FR 23042, Apr. 30, 2010; 76 FR 57450, Sept. 15, 2011]

§ 1065.520 Pre-test verification procedures and pre-test data collection.

(a) If your engine must comply with a PM standard, follow the procedures for PM sample preconditioning and tare weighing according to §1065.590.

(b) Unless the standard-setting part specifies different tolerances, verify at some point before the test that ambient conditions are within the tolerances specified in this paragraph (b). For purposes of this paragraph (b), “before the test” means any time from a point just prior to engine starting (excluding engine restarts) to the point at which emission sampling begins.

(1) Ambient temperature of (20 to 30) °C. *See* §1065.530(j) for circumstances under which ambient temperatures must remain within this range during the test.

(2) Atmospheric pressure of (80.000 to 103.325) kPa and within ± 5 kPa of the value recorded at the time of the last engine map. You are not required to verify atmospheric pressure prior to a hot start test interval for testing that also includes a cold start.

(3) Dilution air conditions as specified in §1065.140, except in cases where you preheat your CVS before a cold start test. We recommend verifying dilution air conditions just prior to the start of each test interval.

(c) You may test engines at any intake-air humidity, and we may test engines at any intake-air humidity.

(d) Verify that auxiliary-work inputs and outputs are configured as they were during engine mapping, as described in §1065.510(a).

(e) You may perform a final calibration of the speed, torque, and proportional-flow control systems, which may include performing practice duty cycles.

(f) You may perform the following recommended procedure to precondition sampling systems:

(1) Start the engine and use good engineering judgment to bring it to one of the following:

(i) 100% torque at any speed above its peak-torque speed.

(ii) 100% operator demand.

(2) Operate any dilution systems at their expected flow rates. Prevent aqueous condensation in the dilution systems.

(3) Operate any PM sampling systems at their expected flow rates.

(4) Sample PM for at least 10 min using any sample media. You may change sample media during preconditioning. You may discard preconditioning samples without weighing them.

(5) You may purge any gaseous sampling systems during preconditioning.

(6) You may conduct calibrations or verifications on any idle equipment or analyzers during preconditioning.

(7) Proceed with the test sequence described in §1065.530(a)(1).

(g) Verify the amount of nonmethane hydrocarbon contamination in the exhaust and background HC sampling systems within 8 hours before the start of the first test interval of each duty-cycle sequence for laboratory tests. You may verify the contamination of a background HC sampling system by reading the last bag fill and purge using zero gas. For any NMHC measurement system that involves separately measuring methane and subtracting it from a THC measurement or for any CH₄ measurement system that uses an NMC, verify the amount of THC contamination using only the THC analyzer response. There is no need to operate any separate methane analyzer for this verification; however, you may measure and correct for THC contamination in the CH₄ sample train for the cases where NMHC is determined by subtracting CH₄ from THC or, where CH₄ is determined, using an NMC as configured in §1065.365(d), (e), and (f); and using the calculations in §1065.660(b)(2). Perform this verification as follows:

(1) Select the HC analyzer range for measuring the flow-weighted mean concentration expected at the HC standard.

(2) Zero the HC analyzer at the analyzer zero or sample port. Note that FID zero and span balance gases may be any combination of purified air or purified nitrogen that meets the specifications of §1065.750. We recommend FID analyzer zero and span gases that contain approximately the flow-